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Albert M. Day, Director

Special Scientific Report No. 61

CONDITIONS AFFECTING SHELLFISH PRODUCTION IN LYNNHAVEN BAY, VIRGINIA, AND THE POSSIBILITIES OF IMPROVING THEM BY INCREASING TIDAL FLOW

by

Walter A. Chipman, Jr.

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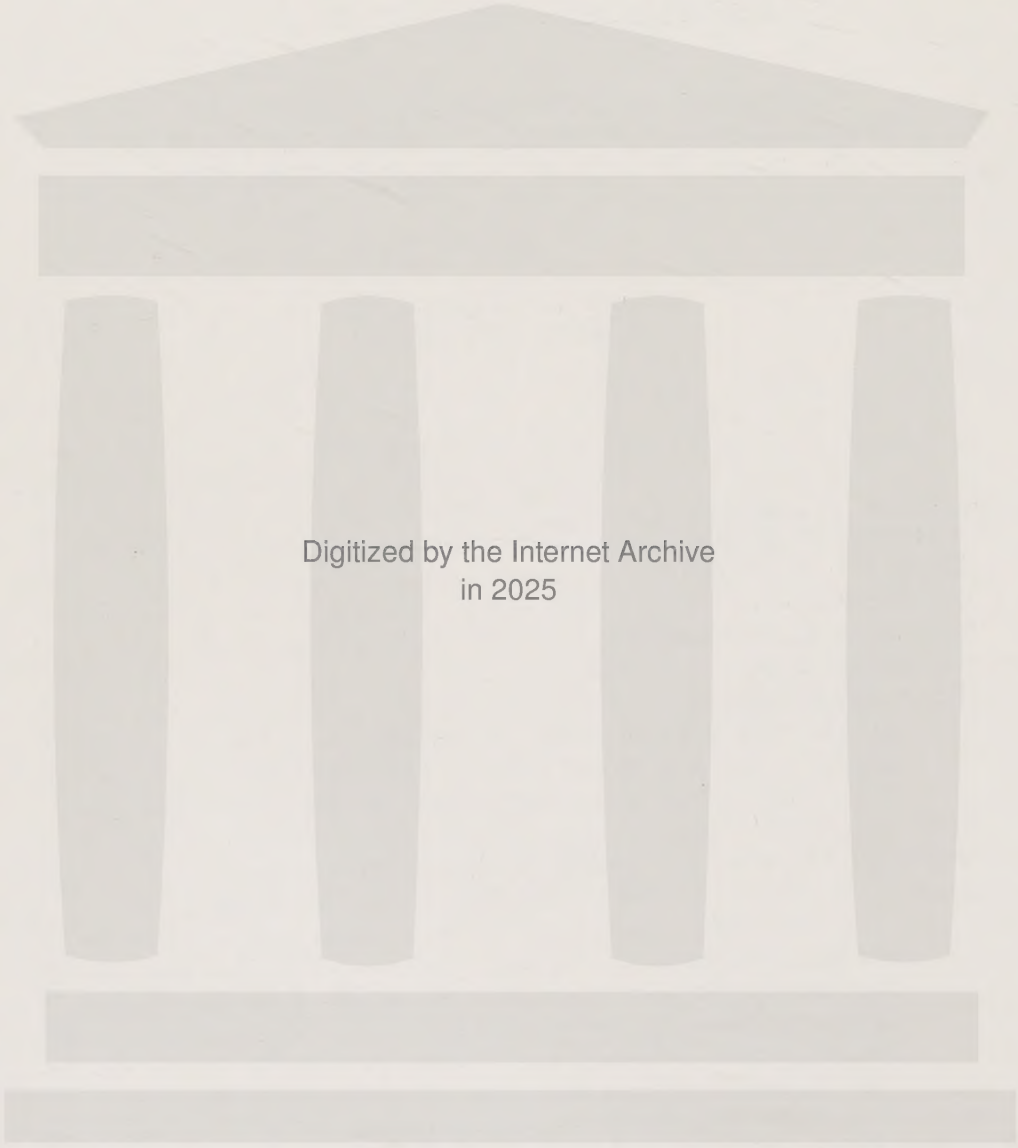

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INTRODUCTION

Description of area

Located just west of Cape Henry, which is the southern point at the entrance to Chesapeake Bay, is Lynnhaven Inlet, a narrow connection between Lynnhaven Roads and Lynnhaven Bay. Lynnhaven Bay, or Lynnhaven River, as it is sometimes called, is in reality a branching arm of the Chesapeake Bay. It is a rather shallow body of water from which extends two prongs, the Western Branch and the Eastern Branch. Immediately inside the inlet there is a narrow channel running easterly known as Long Creek. This ends in a large body of water, Broad Bay, which, through a narrow and very shallow opening called The Narrows, joins a second body of water named Linkhorn Bay. By means of a very narrow channel, Rainey Gut, a connection is made to a third body of water called Rainey Pond or Crystal Lake. A small artificial ditch, constructed for mosquito control, connects Broad Bay and the lower section of Long Creek. These waters are shown in figure 1.

All of the waters within Lynnhaven Inlet are brackish and subject to the action of tides, the inflow and outflow being accomplished through the inlet. There is very little surface drainage and much of the fresh water resulting from rains in the surrounding areas enters by percolation through the porous subsoils of the banks.

With the construction of a highway bridge in 1928, the width of the inlet was reduced more than 50 percent by fill approaches and considerable shoaling of the inland waters resulted. The approximate water areas total 5,095 acres which are divided as follows: Lynnhaven Bay, 1,450 acres; Western Branch, 1,065 acres; Eastern Branch, 770 acres; Long Creek, 83 acres; Broad Bay, 892 acres; and Linkhorn Bay and its branches, 835 acres.

Shellfish production

Earlier, nearly all the area inside Lynnhaven Inlet was used in the production of shellfish. The oysters grown in Lynnhaven Bay have been of the most excellent quality and, because of this, have brought a premium price. To the connoisseur the name "Lynnhavens" designates oysters of characteristic flavor and of a quality not found elsewhere. Consequently the Lynnhaven oyster has been marketed as "fancy" stock to the hotel and restaurant trade.

Leased oyster grounds in Lynnhaven Bay and its branches are extensive. Of the 3,285 acres of water bottoms there are 1,847 acres under lease. This 56 percent constitutes nearly every square yard of available bottom, since much of the upper reaches of these branches is not at all suitable for oyster production. In Long Creek, Broad Bay, and Linkhorn Bay are about 1,810 acres of water bottoms. Of these there were 902 acres designated as public oyster rock. At present there are 293 acres of oyster ground under lease in Long Creek and above. At least 25 percent of all the available oyster grounds are not in use.

The natural oyster rocks, included in the Baylor Survey (Baylor, 1894) as Public Oyster Grounds of Princess Anne County, totaled 986 acres and were located as follows:

Public Grounds No. 1 - All of Broad Bay, 585 acres
Public Grounds No. 2 - All of Rainey Pond, 37 acres
Public Grounds No. 3 - All of Linkhorn Bay, 260 acres
Public Grounds No. 4 - In Long Creek, 20 acres
Public Grounds No. 5 - Lower Lynnhaven River, 84 acres

In former years oysters for planting in the branches of Lynnhaven River were obtained from Broad Bay and Linkhorn Bay and from spawning coves in the river itself. As the supply from Broad Bay and Linkhorn Bay decreased, more oysters for planting were obtained from the lower Lynnhaven River and from the James River. The seed oysters were carefully separated and planted evenly and thinly over the bottom where they remained on the beds for a few years. In some instances large oysters were planted for fattening and the carefully culled stock was not left on the beds more than one season. In these plantings no increase in size was expected.

All the data at hand indicate that the annual production of oysters and clams have been substantially reduced in recent years. The leased oyster grounds in Lynnhaven Bay and its branches produced 108,400 bushels per year during the period 1929-1930 and only an average of 62,400 bushels per year in the period 1940-1945. During the period 1929-1930 there were about 3,000 bushels of oysters per year tonged from public oyster grounds and about 900 bushels per year in the period 1940-1945. It is the consensus among the residents that the quality is not as good as formerly and that this change and the decrease in the production of shellfish has been the result of a lack of sufficient tidal flow and a reduction in the depth of water in the areas within the inlet.

Pollution

In the early days of shellfish production there was practically no pollution of the waters connected with Lynnhaven Inlet. There has been considerable increases in the population of the area, particularly in the vicinity of Virginia Beach and Fort Story. Along the shores there have been built many summer homes and some large dairy farms. As a result of these changes there has been a marked rise in domestic sewage pollution of the waters leading into Lynnhaven Bay. The Town of Virginia Beach has a sewage treatment plant on Little Neck Creek from which the effluent, partly treated, enters the creek and continues into Linkhorn Bay. Because of pollution of the waters, the Commonwealth of Virginia, through the Bureau of Sanitary Engineering of its Health Department, has found it necessary to restrict the sale of shellfish from rather extensive areas within Lynnhaven Inlet. These restricted shellfish-producing areas are shown on the map in figure 1.

Suggested Improvements

In view of the shoaling of the waters within Lynnhaven Inlet and the decrease in the shellfish production thought to result from this, the U. S. Corps of Engineers was directed to investigate the possibility of remedying the situation by making certain channel improvements.[1/] Similar investigations have been made and considered in past years. As presently outlined these improvements would consist of providing an entrance channel, with protecting jetties, through Lynnhaven Inlet into Lynnhaven Bay and additional channels through Lynnhaven Bay to the mouth of each of its branches, the Eastern Branch and the Western Branch. It would also provide for the construction of channels connecting Lynnhaven Bay with Broad Bay and Broad Bay with Linkhorn Bay. The channel widths and depths would be such that normal tidal fluctuations of 0.5 and 1 foot would result in all the upper reaches of the waters within Lynnhaven Inlet.

The present survey was carried on for the purpose of estimating the shellfish production of the area and to consider what effect increased tidal flows produced by the suggested improvements would have on it.

The survey was made possible by the cooperation of the Virginia Commission of Fisheries which gave the time and assistance of its oyster inspector for the area, Mr. Clyde C. Absalom, and provided a boat for much of the survey work. Valuable assistance was given by the Norfolk District of the U. S. Corps of Engineers which supplied men for the survey, boats, and provided much data on soundings and tidal fluctuations.

SURVEY OBSERVATIONS

Water Conditions

Examination of the water conditions within Lynnhaven Inlet was made with particular emphasis on salinity and tidal changes. In order to investigate the effect of domestic sewage pollution, samples of water for dissolved oxygen content were taken at the head of Linkhorn Bay where the greatest amount of this pollution occurs. Measurements of the tides and currents in the various waters, made previously by the Corps of Engineers, were studied.

1/ Information supplied by the U. S. Engineer Office, Norfolk, Virginia.

Horizontal distribution of salinity

In order to determine the horizontal distribution of salinity a collection of samples was made at half-mile intervals starting at a station just above the railroad bridge at the inlet and continuing up each branch. These samples were taken on the flood tide in order to have the sampling at each station at approximately the same stage of the tide. The results of this study are given in figure 2, which shows the location of isohalines computed from these data.

The measurements show striking uniformity in the distribution of the water salinity. A steep gradient over the oyster-producing bottoms was lacking. This may be due to the small amount of surface runoff, Lynnhaven Bay or River, as pointed out previously, being more of a branching of Chesapeake Bay than a tributary. During the spring lower salinity over the oyster-growing bottoms has been reported by oystermen of the area and by the State Health Department in its observations made in connection with pollution surveys. There is, however, no information as to gradients in salinity over the oyster grounds at that time of year.

The salinity observed over the oyster beds varied from about 20 to 24 parts per thousand and was well within range in which good oyster production may be expected.

Salinity of the water during tidal cycles

The changes in the height of tide, the salinity of the water, and the water temperature were observed during 13-hour periods at Lynnhaven Inlet, in the Western Branch, in the Eastern Branch, in Long Creek, in the drainage canal from Broad Bay, in Broad Bay, and in Linkhorn Bay. These observations are plotted on the graphs of figures 3 to 9.

As may be expected in such shallow bodies of water the water temperatures followed very closely the air temperatures and changed with the time of day. There was no correlation of temperature with the stage of tide.

The observations made at the draw span at the inlet, figure 3, indicate an appreciable rise and fall of the tide in height, the extreme measuring 2.7 feet for the tide observed. The salinity change during the 13-hour tidal change was very slight, the sea water moving back and forth with very little dilution with fresh water. As a matter of fact, the salinity decreased on the flood and increased on the ebb, a situation that is opposite to what would be expected in a tributary. This indicated that the sea water in Lynnhaven River had become slightly more salty than in the water outside the inlet as a result of evaporation in the shallow water areas on the inside.

At stations in the Western Branch and Eastern Branch of Lynnhaven Bay, figure 4 and 5, there was a fair amount of rise and fall

of the tide. The differences in height between high water and low water were 2.1 and 2.0 feet. The salinity changes indicated movement of the sea water back and forth with some dilution of the sea water with fresh water in the Western Branch, and almost no dilution or change in the Eastern Branch.

At stations in Long Creek and the drainage ditch, figures 6 and 7, there was a fair flow of tide and change in height. The differences in height were 1.5 and 0.8 feet. The creek and canal are shallow and very narrow, and hence do not allow a great exchange of water from the areas above with that at the inlet. Differences in salt content of the waters above and below the creek and canal were observed during the tidal cycle, but these were slight, ranging only from 1.0 to 1.5 parts per thousand.

Changes in the height of water and the salinity in Broad Bay and Linkhorn Bay during a tidal cycle were extremely slight. The results of observations in these bodies of water are given in figures 8 and 9. In height the tidal differences were but 0.25 and 0.2 foot. The observations were made during rains and a slight decrease in the salinity of the water may have resulted from runoff, since the observation points were not away from the shore and, for Linkhorn Bay, the station was very close into a cove. However, the observations show that the sea water within Broad Bay and Linkhorn Bay is not diluted to a great extent by fresh water and that it has a tendency to stagnate, only being exchanged with fresh sea water from the inlet during times of extreme tides.

Dissolved oxygen, pH, and other water conditions

There was nothing indicating an abnormal environment for oysters as regards water temperatures or pH. The observations of the dissolved oxygen content of Linkhorn Bay were made as indicators of the effect of sewage pollution on the upper portions of this Bay. The dissolved oxygen content was close to 100 percent of saturation and was sufficiently high to assume that there was no situation existing in the waters which would be dangerous to aquatic life so far as oxygen requirements are concerned.

Tide and tidal flow

Observations on the flow of tide through Lynnhaven Inlet and within Lynnhaven Bay and its connecting waters have been meager. There were no observations as to flow made in this survey but height of tide was recorded at the inlet, in the Western Branch, in the Eastern Branch, in Long Creek and the canal, in Broad Bay, and in Linkhorn Bay during tidal cycles.

The U. S. Corps of Engineers, in connection with gathering data for its studies, measured the currents and tides within Lynnhaven Inlet and made detailed observations of bottom contours, nature of the bottom from core samples, etc., so that plans could be made for improving the inlet. Stages of tide were recorded at many points and tidal currents at stations across the lower bay within the inlet, and in Long Creek were measured.[1/] From these data of flow, and the bottom contours along the line of stations computations were made of the volume of water passing through the inlet on flood and ebb tides.

The normal flood velocity into Lynnhaven Bay ranged to 2.50 feet per second and the normal ebb velocity out of the bay to 2.93 feet per second. In Long Creek the normal flood velocity was 1.32 feet per second, and the normal ebb velocity 1.79 feet per second.

The flood tide into the bay was computed to be 244,047,600 cubic feet and the ebb tide out of the bay 257,644,800 cubic feet. The flood tide in Long Creek was 16,237,800 and the ebb tide 19,892,900 cubic feet.

Readings of the tide gauge stations within the inlet showed differences in the height of the tide between high water and low water similar to those observed in the present survey and previously mentioned. There was very slight fluctuation of the water level in the areas above Long Creek within Broad Bay and Linkhorn Bay, the range being only about 0.25 foot. There was considerable change in level in the Western Branch and Eastern Branch of Lynnhaven River. The tidal range on the days observed was found to be nearly the same at the inlet region and the upper reaches of these branches, nearly 2 feet.

Exchange of water by tidal action

Examination of the bottom contours shows that Broad Bay and Linkhorn Bay are relatively deep, with shallow and narrow connections with the inlet. The amount of water flowing into these bodies of water with the tide is extremely small and it is only at a time of extreme low or high tides that there is much exchange. There is very little movement of the water in Broad Bay and Linkhorn Bay.

The Corps of Engineers has made many soundings along bottom contours throughout all the waters within the inlet. From these data it was possible to find the average depth of water in feet at mean low water for the various branches and bays. Using these averages and the acreage of water bottoms it was possible to compute the volume

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1/ Unpublished data

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of water within the inlet. The results of these computations, presented in table 1, show that the total volume of water within the inlet may be estimated as 493,915,514 cubic feet for Long Creek and the waters above it, and 342,768,805 cubic feet for Lynnhaven Bay and its two branches.

Measurements of the tidal flow made in Long Creek showed a volume of approximately 18 million cubic feet passing on each tide. This would mean a tidal exchange of the waters of Long Creek and above of 3.5 percent. The amount of flow into Lynnhaven Bay on a tide was approximately 250 million cubic feet. The exchange for Lynnhaven Bay and its two branches, the Eastern Branch and the Western Branch, would be this amount less the exchange into Long Creek, or 232 million cubic feet on each tide. This would mean an exchange of the water of Lynnhaven Bay and its two branches of 40 percent on a tide.

Character and distribution of the oyster-growing bottoms

There is considerable diversity in the character of the bottoms in the tidewater area of the Chesapeake Bay. The bottoms are predominantly of hard sand, soft mud, and varying mixtures of the two. Bottoms with stony material and gravel are much less common.

Bottoms that are of soft mud and bottoms of hard sand that is subject to shifting from the action of storms, etc., are not suitable for oyster growth and production. Firm mud, containing a mixture of these two, constitutes the bottoms on which natural oyster growth occurs and is the most desirable for use in the cultivation of this shellfish. It is true, of course, that soft bottoms can be strengthened by the use of shells or gravel and that some shifting sands can be anchored and these bottoms, when thus changed, can be utilized for the growing of oysters. The bottoms containing both sand and mud have these in varying amounts, so that the firmness and consistency of oyster-producing areas are different in their nature at different locations.

The bottoms of the inland waters within Lynnhaven Inlet were carefully examined throughout. By slowly passing over in a small boat and probing with a pole and oyster tongs, the nature of the bottom was determined and the presence or absence of shellfish ascertained. In addition, samples of water, marine life, and muds were collected and examined at the sampling stations indicated on the chart in figure 1. The hydrographic data are given in table 2.

Western Branch

The Western Branch of Lynnhaven Bay, comprising some 1,065 acres of water area, is plotted by the State into parcels and leased to oyster growers. These bottoms, covering nearly every square yard, extend from the lower bay into Thurston Branch and Buchanan Creek.

The upper end of the plotted oyster beds lies approximately 1/2 mile above the mouth of Thurston Branch and about the same distance into Buchanan Creek.

The uppermost station visited (73) was located at the limit of the plotted oyster beds in Thurston Branch. The water was shallow with a depth of 1 foot at the time of examination. That the salinity of the water is not a factor in limiting the extent of the oyster beds into this branch is shown by the observed reading of 20.9 parts per thousand. The water temperatures were normal for the season and not inimical to shellfish production. The bottom is soft and, because of the predominance of silt, is not considered as being suitable for the planting of oysters since the majority would sink below the surface and be smothered. It was reported that formerly many oysters were grown in this immediate area but no oysters were found and it seems reasonable to suppose that silting has resulted in conditions limiting oyster culture in this branch.

Station 58, located just below the site of an old bridge below the junction of Thurston Branch and Buchanan Creek and just off Donation Creek, lies just below the line which restricts the sale of shellfish because of domestic sewage pollution. The depth of water was 3 feet. The bottom is soft, but firmer than in Thurston Branch. It was stated that this section was somewhat deeper, had a firmer bottom, and used to produce good oysters. At present it seems probable that oysters would sink too deeply into the mud to grow. If the bottom could be stiffened it might be possible to utilize this area. Just below this area are bottoms sufficiently firm for the cultivation of oysters. No oysters were obtained on these grounds and there appears to be little cultivation above Hebden Cove.

There are a few small plots of ground in Hebden Cove under lease. These extend up the cove about 0.4 mile. At the time of examination the depth of water (Station 84) was 2 feet and the salinity at the first of ebb tide was 21.44 parts per thousand. The bottom in the cove was found to be a sticky mud sufficiently firm for the cultivation of oysters. Indications were that there are softer bottoms in the upper reaches of the cove, a condition typical in these waters. No oysters were found on the beds and there was no indication of much, if any, growing of oysters in the cove.

On the eastern shore of Witch Duck Point off Hebden Cove (Station 57) the bottom is a firm, stiff mud with a fair amount of fine sand in it. This is very good oyster bottom but no oysters were found at the location of the station. It was reported that grounds in this area produced the fattest oysters of any in the region last year and that they always produce a fat oyster. It is

TABLE 1.--Volume of Water Within Lynnhaven Inlet

Location	Water area in acres	Average depth in feet at mean low water	Volume in cubic feet at mean low water
Long Creek	83	2.78	10,051,034
Broad Bay	892	6.05	235,075,896
Linkhorn Bay	835	6.84	248,788,584
Lynnhaven Bay and its branches	3,285	2.39	342,768,805

TABLE 2.--Hydrographic Data

Station	Cruise	Date	Time	Tide	Depth	Water Temperature Surface	Water Temperature Bottom	Water Salinity Surface	Water Salinity Bottom	Water pH Surface	Water pH Bottom
		1947		(1)	feet	°C	°C	‰	‰		
50	01	6-17	9:35	F.E.	1.8		24.8		23.30		8.1
51	01	6-17	10:15	E	3.2		24.6		23.40		8.0
51	14	7-15	10:45	½E	2.0		27.0		21.73		-
52	01	6-17	10:40	E	3.5		24.4		23.40		8.0
52	14	7-15	11:00	½E	3.5		27.0		22.12		-
53	01	6-17	11:10	E	1.5		24.5		23.88		8.2
53	14	7-15	11:20	E	-		26.2		22.52		-
54	01	6-17	11:25	L.E.	15.0	23.9	23.8	24.40	24.12	8.0	8.1
55	02	6-17	14:37	F.F.	1.5	-	27.2	-	24.12	-	8.4
56	02	6-17	15:00	F	4.5	-	26.4	-	23.82	-	8.1
57	02	6-17	15:15	F	8.0	26.8	26.3	22.16	22.68	8.4	8.0
58	02	6-17	15:30	F	3.0	-	27.5	-	21.23	-	8.2
58	15	7-16	9:40	E	4.8	-	26.2	-	21.18	-	-
59	02	6-17	15:45	F	1.0	-	28.4	-	19.93	-	8.2
60	03	6-19	11:35	HWS	12.5	26.0	25.9	19.06	20.11	8.3	7.5
61	03	6-19	11:50	HWS	12.0	26.0	25.9	19.04	20.11	8.3	7.6
62	03	6-19	12:00	F.E.	14.0	25.9	25.8	19.81	19.84	8.4	7.8
63	03	6-19	12:20	F.E.	6.0	-	25.2	-	20.07	-	8.3
64	03	6-19	12:35	E	11.0	25.3	25.1	20.11	21.18	8.4	8.0
65	03	6-19	13:20	E	8.0	-	24.4	-	21.96	-	8.3
66	03	6-19	13:40	E	-	-	24.2	-	22.72	-	8.2
73	15	7-16	9:28	E	1.5	-	26.2	-	20.91	-	-
74	15	7-16	10:15	E	2.0	-	26.2	-	21.44	-	-
69	15	7-16	10:30	E	5.5	-	25.2	-	23.91	-	-
75	16	7-16	14:45	E	7.5	-	26.8	-	20.63	-	-
76	16	7-16	15:40	L.E.	2.5	-	28.4	-	18.95	-	-
77	16	7-16	17:00	E	12.5	-	27.4	-	19.79	-	-

(1) E = Ebb; F = Flood; F.E. = First of Ebb; L.E. = Last of Ebb;
F.F. = First of Flood; L.F. = Last of Flood; H.W.S. = High Water Slack.

likely that these grounds will be rather extensively planted later with oysters obtained from beds closer to the inlet. Slightly below station 57 and along the shore of Witch Duck Point were found some grounds planted with oysters.

Continuing around Witch Duck Point were 21 acres of leased ground on which had been planted 2,000 bushels of oysters. They were in good condition. The bottom here is mud and sand, making a very hard bottom which would support many oysters.

Witch Duck Bay contains oyster grounds but they are not being used. The upper portion of the bay tends to have a softer bottom. The marketing of oysters from the bay is restricted by the State Health Department because of pollution.

Across from Witch Duck Bay and off Carraway Point (Station 56) the mud, containing considerable sand, makes an excellent oyster-growing bottom. The water depth was 4.5 feet. The beds were planted with many oysters, estimated at 600 bushels to an acre.

At the mouth of Thoroughgood Cove the bottom is sand with mud and very firm. No oysters were found on these beds. Continuing down this shore were leased oyster beds but no oysters were found planted on the grounds at the time.

Oyster beds continue into Pleasure House Creek where there is considerably more mud than sand. Although these grounds are better for fattening than those off Thoroughgood Cove, the area is restricted for the taking of shellfish because of pollution.

Extending along the eastern shore of the Western Branch above Hill Point, and continuing around the point, are natural oyster reefs. These reefs extend for a considerable distance along the shore and large areas are exposed at low tide. These oyster bottoms are very thickly covered with oysters of all ages which grow in clumps and clusters with but few singles. The clumps are very easily broken apart by pressure of the hands and the oysters easily culled. The larger oysters on these reefs should be moved and sold and the smaller oysters culled and placed on other grounds farther up the branch for growth and fattening. Setting is very heavy in this area of lower Lynnhaven Bay.

The lower portion of the Western Branch and Lynnhaven Bay close to the inlet has a considerable amount of shifting sand and much of it is not suitable for oyster cultivation.

Eastern Branch

The oyster beds of the Eastern Branch of Lynnhaven Bay extend a short distance above West Point and Wolfsnare Point into

London Bridge Creek and Pinetree Branch.

The farthest point examined was off West Point at station 50. The salinity was 23.3 parts per thousand. The bottom is moderately firm mud, having a small amount of fine sand in it. There were but few oysters on the bed and they were nearly covered with silt.

Off Smith Point the bottom is more firm than above. There were a few oysters at this location.

Oyster grounds extended well into the cove below Smith Point. The acreage in this cove under lease totals approximately 20 acres.

The bottom off Trants Point (Station 52) consists of mud with considerable sand. It had but few oysters.

Farther down, below Sandy Point and along Poorhouse Cove, the bottom is firm mud containing a considerable amount of sand.

Off Avery Island were found very good oyster bottoms and there were more oysters in this area than above. The oyster grounds extend into Brock Cove, Hog Pen Creek, and other coves and bays along this shore.

Along the eastern shore of Eastern Branch from Brock Cove to the mouth of Long Creek are oyster beds, with natural reefs in the lower section lining the shores. The bottom is hard sand and contains very little mud. On the opposite shore the bottoms are also hard sand and the oyster grounds are populated from natural set. These grounds tend to take on the character of thick oyster reefs. There is little cultivation of oysters. The oysters growing there from natural set are gathered and marketed when they reach sufficient size.

Public Oyster Grounds No. 5, consisting of 84.0 acres, extends from a line across Lynnhaven Bay from a point about 0.4 mile above the mouth of Long Creek on the eastern shore to a point on the western shore just below Pleasure House Creek and across the bay to Hill Point in the vicinity of the entrance to Parker Cove.

The area of restricted shellfish production in the Eastern Branch extends nearly to the end of Trants Point. This restriction on shellfish production has resulted in much of the bottoms above Trants Point not being used.

Linkhorn Bay

In Linkhorn Bay the water is from 12 to 14 feet deep and the bottom is hard mud and sand. This bay contained Public Oyster Grounds No. 3, which extended from shore to shore from The Narrows to a point approximately 0.7 of a mile above the tip end of Bird Neck Point and

comprised 260 acres. At present oysters are found in the lower part below Alanton. It was stated that several people previously held oyster grounds under lease in the upper portion of Linkhorn Bay but that all had given up their grounds as unprofitable. The claim is made that the beds were injured by the effluents of the sewage plant that are emptied into Little Neck Creek, one of the prongs at the upper end of Linkhorn Bay.

In the lower portions of Linkhorn Bay oyster grounds under lease total about 166 acres located within the coves for the most part. They are not planted grounds, the owners depending on a natural set of oysters for their supply.

Crystal Lake, shown on the chart of Public Oyster Grounds of Princess Anne County as Rainey Pond, lies east of Linkhorn Bay and connects to it by a very narrow channel known as Rainey Gut. This body of water contained Public Oyster Ground No. 2, comprising 37.0 acres. No examination was made, but it was stated that this body of water was entirely out of oyster production.

All the waters above The Narrows, including Crystal Lake and Linkhorn Bay and its branches, are in a restricted shellfish area because of sewage pollution.

Broad Bay

Broad Bay is a rather wide expanse of water, 8 to 10 feet deep, which connects with Linkhorn Bay through The Narrows and with Lynnhaven Inlet through Long Creek. A canal, constructed to aid in mosquito control, connects the lower part of Broad Bay with the lower portion of Long Creek. The bottom in Broad Bay is of hard mud with much sand and has some shells and few oysters. Although the bottom is very firm, there is a considerable amount of silt on its surface.

Public Oyster Ground No. 1, which included nearly all the bay, contained 585.0 acres. From examination of the beds just above the entrance of Long Creek (Station 64) and along the eastern shore it was observed that there were very few oysters on the bottom and that they were well covered by a layer of silt, the majority to about 2/3 of their length. Oysters of all ages were found, including some spat. There was an abundance of egg cases of the oyster drill, Urosalpinx cinereus (Say), and many worm tubes, sponges, and other fouling organisms. The oyster bottoms under lease along the western shore of Broad Bay are rather large and extend about its entire length. These are not planted beds. The lessors depend on natural set and simply remove marketable oysters.

The public oyster grounds of Broad Bay are badly depleted. Very few licenses have been issued to tongers working on these grounds since a small catch makes this oystering activity hardly worth while.

Long Creek

The upper portion of Long Creek has a bottom of hard mud with sand. In the cove opposite Carter Point and below this cove on the Carter Point shore are leased oyster bottoms.

Public Oyster Grounds No. 4 consists of 24.0 acres extending from the small island off Carter Point down Long Creek for a distance of about 0.7 mile. This public oyster rock is depleted.

Below the public rock is an area of hard sandy bottom opposite the Sand Dune. Farther down the creek the bottom is hard mud with some sand.

From above the bridge on the London Bridge road to the bay are grounds under lease. The bottoms are mostly hard sand with natural oyster rocks along the shores.

DISCUSSION AND CONCLUSIONS

Originally the request was made that the Service make a survey and prepare a report on existing water conditions affecting the production of shellfish within Lynnhaven Bay and its connecting waters. It was further requested that the report include statements as to the increase in the exchange of water that is needed to provide ideal conditions for the growth and cultivation of shellfish, the location and present value of existing cultivated oyster grounds, the possible enhancement in value of existing cultivated oyster grounds in the event that the flow of water is increased, and the location and potential value of additional oyster grounds which could be cultivated in the event that the flow of water is increased to provide ideal conditions.

It should be pointed out that, although progress has been made in increasing our knowledge, the science of oyster biology and oyster farming is not as exact and precise as certain other sciences. We are dealing with living organisms which are, in themselves, complex machines, affected by innumerable factors acting in complex ways from the outside environment. With this limitation in mind, the following discussion is presented.

Oysters are brackish water forms. They are not found in the sea, but in sheltered areas such as coves, bays, and estuaries, where there is some drainage from the land. Oysters grow and reproduce to best advantage in waters where the salinity range is approximately from 14 to 29 parts per thousand.

At the start of the survey, not knowing the salinity regime of the waters within Lynnhaven Inlet, it was thought that, if the

enclosed waters had been markedly cut off from the Chesapeake Bay they would have become altered in salt content and perhaps have become less suited for the growing of oysters. Measurements of salinity, however, made during the survey in June and July showed salinities varying from 20 to 24 parts per thousand over the oyster-producing bottoms. These may be compared with salinities observed some 33 years ago at various locations throughout the waters within Lynnhaven Inlet by the U. S. Public Health Service (Cumming, 1916). These observations, made on October 5, 1914, at 2 locations in Broad Bay, 2 locations near the mouth of Long Creek, 5 locations in the Western Branch, and 1 location in the Eastern Branch, show a range of salinity from 22 to 25 parts per thousand. It is evident that the salinity of the waters is not now significantly different.

Considering the water conditions within Lynnhaven Inlet there was nothing indicating that the oyster population was being adversely affected by the concentration of total salts in the water. The salinity regime is such that normal oyster growth and reproduction may be expected. Observations of pH and oxygen of the waters of Lynnhaven Bay and its branches show no indications of abnormalities that would influence oyster production.

Pollution of the waters within Lynnhaven Inlet from sewage has been increasing as the surrounding areas have become more populated. It has a marked effect on the shellfish production since oysters grown in waters that receive this pollution cannot be marketed unless moved to clean waters for purification. As this shifting of oysters involves additional expense, the tendency is to allow these grounds to become idle and the acreage available for the conditioning of oysters for market is reduced. Because of this inactivity and lack of working of the grounds sedimentation is increased and clean material for the attachment of oyster spat is made less available. As a consequence the grounds included in restricted shellfish areas decrease in value. This pollution of the waters by domestic sewage has been an important factor in reducing the shellfish production in Lynnhaven Bay areas. A decrease in the amount of such pollution will be beneficial to oyster production in these waters. Increasing tidal flow in the waters within Lynnhaven Inlet will change the distribution of the restricted areas but the factors involved are complicated and make predictions of such effects difficult.

Knowing that the oyster feeds on the microscopic plants and animals which are carried into the shell by the water currents created by the oyster, it is not unreasonable to assume that the fattest and more rapidly growing oysters would be found in areas where there is an abundance of this food. The food organisms of the oyster depend on the organic material and gases in the water surrounding them and are in greater abundance on mud bottoms. Growth and abundance

of these food organisms depends to a great extent on the fertilizing value of the materials brought into the smaller tributaries from the soil of surrounding areas. There can be little question that the more or less quiet waters in the upper reaches of creeks and inlets are more favorable for a greater production of oyster food, and such waters should produce oysters of better quality than those where the waters are more turbulent. That this is true is well known to the practical oyster growers who transplant their oysters to small coves in the upper reaches of branches for conditioning. Oysters grown in shallow water seem to fatten earlier and to a greater degree than oysters in deeper waters. This, undoubtedly, is connected with conditions of temperature and other factors compatible with a greater productivity of the oyster-food organisms.

Oysters growing in the upper reaches of branches where there is little current may be smothered by the accumulation of mud. Sedimentation in such small coves and creeks is due to the accumulation of organic debris arising from plant growth and leaf material from the surrounding shores. This natural phenomenon, observed many times, is responsible for the gradual filling of the upper portions of coves and creeks in our tidal waters. This situation is even more pronounced in shallow bodies of water which receive their tidal exchange through narrow channels.

Silting creates a distinct disadvantage to the oyster. The free-swimming oyster larvae must finally settle upon a hard, smooth surface that is not covered by sediment in order to continue its existence and become a sedentary organism. If suitable places for attachment are lacking, oyster larvae may settle on the mud or sediment and die. Adult oysters partially embedded in soft mud often are forced to combat this menace by greater activity and by the secretion of a shell covering for the mud that does enter the shell cavity. This fighting for existence against soft mud necessarily weakens the oysters and makes them less suitable for marketing.

Oyster grounds that are continually being used by oyster growers and planters are kept more free of this accumulation of soft mud by reason of the working of the beds. If the water currents are slight and the grounds are not used they deteriorate from this accumulation.

It is difficult to judge the rate of flow of water and an observer has a tendency to overestimate the rate of flow. The rate near the bottom is only a fraction of that of the water above. Although the rate of flow over a particular bottom is greatly influenced by the depth, contour of the surrounding bottom, etc., there will be a flow of water of fair amount where there is an appreciable rise and fall of the tide.

The minimum rate at which water should flow over oysters or cultch used for the attachment of the spat in order to keep this

material clean and free of sediment is not known. It was pointed out by Grave (1912) that observations made by timing current poles released from boats anchored over oyster beds demonstrated that a flow of about 0.5 to 0.6 mile per hour existed over some of the best oyster-producing beds. Flows somewhat greater than this may be desirable.

The belief that rapid flowing water is necessary to produce oysters of fine quality is not well founded. Some flow is necessary to move the food organisms across the beds. The carrying power of the water is greater when its flow is rapid than when it is slow, and the water quickly loses this carrying power as its rate of flow decreases. Water flowing from tidal action picks up sediment and oyster-food organisms from the bottom, distributes these materials over an area, and allows them to settle as the flow ceases at the change of tides during slack water. Thus the action of tides brings material from some distance from the oyster bed and allows it to settle and become available to the oysters.

A current of slow velocity and small volume may be able to carry a food supply sufficient for a certain number of oysters but entirely too small for a greatly increased number. This factor must be considered in all planting operations. It is well known that the waters of Lynnhaven Bay are such that plantings must be limited to a maximum of 150 bushels per acre on the best producing bottoms and to not more than 100 bushels per acre on others that are not as good. This is correlated with the inadequacy of the oyster food supply for more densely planted beds.

Aside from the fact that the oyster-food content of the water varies greatly, we do not know just how much food is needed per day by oysters of different ages or sizes to maintain their growth and to allow for the storage of reserves. Some progress has been made in observations as to the quantity of water filtered by the oyster to obtain its food and satisfy its respiratory needs.

Although the rate of water filtration of an oyster varies because of many influencing factors, rates of pumping have been measured ranging to nearly 30 quarts an hour (Galtsoff et al, 1947; Loosanoff and Engle, 1947). An adult oyster may filter an average of 16 quarts an hour during a period of 20 hours per day of activity, or a total of 80 gallons per day.

The amount of water filtered by a bed of oysters is tremendous. We may obtain some concept of this volume from the following considerations. An acre of bottom planted with 100 bushels of adult oysters would have approximately 25,000 oysters, or 5 oysters per square yard. This density of planting is not great. Filtering 4 gallons an hour, the oysters on the above acre of bottom would filter 100,000 gallons of water an hour. The volume of water over an acre of bottom having a water depth of 3 feet would amount to nearly a

million gallons. The oysters on that acre would filter all the water above them in about 10 hours. In an area containing 3,000 acres the oysters would filter 300 million gallons an hour.

There is, of course, multiplication of the oyster-food organisms in the water, but it is evident from a consideration of the filtering capacity of oysters that movement of the water over the oyster beds is necessary to furnish a new supply of food organisms.

Although the water areas in Lynnhaven Bay and its branches total 3,285 acres, water depths are not great. The average depth from the thousands of soundings made throughout the entire water bottoms was only 2.39 feet. Computations made of the water passing into this area on a tide show that 40 percent of the water within this area is exchanged on a tide. Movement of the water over the oyster beds in these areas resulting from this exchange should adequately meet the needs of the oysters. It should allow good distribution of the oyster-food material. In the lower areas the currents keep the places for attachment of oyster larvae clean and distribute the larvae, as evidenced by the excellent rate of natural reproduction with the formation and continuation of natural oyster bars where suitable bottoms exist. Shifting sand near the inlet limits the extent of these beds. In the upper reaches of the Eastern Branch and the Western Branch there is an accumulation of silt which produces bottoms unfavorable for oyster culture. Sedimentation is a natural process in the headwaters of this area and it is unlikely that even a greater flow of water back and forth will prevent such accumulation over a long period of time.

In Broad Bay and Linkhorn Bay, where there is only about 3.5 percent exchange with the tide, and currents are very slight, the picture is different. The areas of Broad Bay and Linkhorn Bay which are public oyster grounds, are nearly barren of oysters. Coverings of silt were seen on the oysters and bottoms with very little clean surface for the attachment of oyster larvae available. Aside from the natural oyster enemies present, the lack of suitable places of attachment means these beds are not conducive to the reproduction of oysters. Even a moderate amount of oyster-fishing would soon depopulate them. Increasing the production of oysters from natural reproduction on the beds in Broad Bay and lower Linkhorn Bay is dependent on more cultch for the attachment of oyster spat and a much greater flow of water to keep the cultch clean. The improvements contemplated by the U. S. Engineers provide for an exchange sufficient to allow tidal fluctuations of from 0.5 to 1 foot in the upper reaches where the existing range varies from 0.1 to 0.2 foot. Tidal exchange of this magnitude in the upper reaches of Linkhorn Bay will improve the natural oyster production of Broad Bay and Linkhorn Bay.

It should be pointed out that the proposed improvement will not in itself perform a miracle and greatly increase oyster production. There is need for oyster cultural activities by governmental groups and by individuals.

Within Lynnhaven Inlet the portion of the leased bottom actually used in oyster production is relatively small. There is an extremely small amount of oyster farming being carried on in Lynnhaven Bay and many of the people leasing oyster grounds either let the grounds stand idle or merely market whatever crop happens to grow on their grounds. The public rocks of the area are depleted and no attempts were made to stabilize production of these before depletion and no attempts have been made to increase their production. Lack of sufficient depth of water for the use of boats necessary for much of the work has been one of the limiting factors.

Cultivated oyster grounds should mean grounds that are actually used in oyster farming on which the best practical techniques known in oyster culture are followed. Stabilization at current levels or increased production in various areas is often possible only if careful cultivation is practiced.

The transfer of large oysters from areas where they are growing to the upper regions of the branches of Lynnhaven Bay for conditioning and fattening has been carried on since the time of the early settlers. It is a result of this practice of relaying the oysters that has given the Lynnhaven oyster its name. Careful planting of a select stock in not too great an amount is the basis for continuation of the Lynnhaven oyster industry. Its future depends on the proper maintenance of grounds and the obtaining of suitable stock for planting.

The oyster grounds in the upper portions of the Eastern Branch and the Western Branch have decreased in value from silting. In the Western Branch there appears to be little prospect of utilizing grounds lying in Thurston Branch and Buchanan Creek, and slight prospect of utilizing grounds above Hebden Cove. In the Eastern Branch the upper areas of leased bottoms have considerable silt, but there is little acreage now under lease that could not be utilized in oyster production. However, the areas above Trants Point are within a restricted shellfish area because of sewage pollution and this limits the possibilities of shellfish production of this branch.

It seems that the Western Branch below Hebden Cove could be utilized to a greater extent for the relaying and planting of oysters. It is here that increases in the production of oysters within the upper sections appears to be the most promising.

The lower section of the Western and Eastern branches and Lynnhaven Bay have very good oyster-producing grounds. Planting of

cultch and careful culling of the natural oyster-set and the planting of seed oysters on the bottoms more distant from the inlet would allow a greatly increased yield. Lack of cultivation is one of the chief reasons these bottoms are not producing to their full possibilities. This lack of utilization of the grounds has been attributed to failure of the oysters to do well and insufficient water depth for the operation of boats.

The grounds in Broad Bay and Linknorn Bay present a different situation. It is in these bays that the greater part of the public oyster grounds were established and the oysters for relaying were obtained until the supply was exhausted. These grounds were natural setting and growing grounds.

Along the shore and in the coves of the lower half of Linkhorn Bay is a very limited supply of oysters. The leased grounds above the Narrows have a very small production. There is no cultivation of the bottoms and the small amount of natural set is allowed to grow and the larger oysters removed for transplanting. If the Narrows were not as shallow and small, and if pollution were not a factor, the lower portions of Linkhorn Bay could be utilized to a limited extent as an oyster growing area.

Broad Bay contains the last active public oyster rock of the area. As a public oyster ground it is nearly out of production. Every indication is that this body of water was never a seed-oyster producing area of any great consequence. There was limited reproduction and growth of oysters, an amount so small that depletion was inevitable with even a moderate amount of oyster-fishing. Oyster enemies and the lack of clean cultch keeps reproduction and development at a low level. At present oysters are scarce and the amount of sediment is great. Lack of tidal movement contributes much to this accumulation of silt and the rapid fouling of the cultch. Because of its lack of qualities of a seed-producing area, building up of these oyster grounds by supplying clean cultch would not appear to be recommended. It is more logical to develop these grounds for the growing of oysters where seed may be planted and be expected to produce a good yield. With increased tidal flow and water exchange it would appear that these grounds in Broad Bay would be very valuable if so utilized. The need for waters navigable for the oyster boats engaged in such activities in Broad Bay becomes apparent.

Grounds under lease in Broad Bay are not being cultivated and are in about the same situation as the grounds not under lease. The need for cultivation of these grounds rather than a dependence on natural reproduction and growth is clearly seen. The same situation exists on the oyster grounds in the upper portions of Long Creek.

Deepening of the entrance channel and provision for channels into the Eastern Branch and Western Branch would allow easy access to the oyster grounds by boats engaged in the bringing in of shell and seed oysters. With this provided, together with some increased exchange of tide, the latter being of lesser consequence, shellfish production could be increased in Lynnhaven Bay and its two branches so that the leased bottoms could produce, with proper cultivation methods, 100 to 150 bushels per acre. For the 1,847 acres, of which some 30 percent is not usable or is of limited use, the annual production would approximate 150,000 bushels, or about double the present annual production.

Dredging of an adequate channel to connect Broad Bay with the inlet and dredging of The Narrows into Linkhorn Bay, which would provide a tidal exchange increase in these waters over its present value, would provide conditions more favorable for the natural reproduction of the public rocks of these areas by keeping cultch clean for the attachment of oyster spat and provide better distribution of the larvae. The planting of cultch, such as shell, would be needed. However, natural production of oysters in these waters would never be great, but could possibly be sufficient to support a moderate fishery producing some 7,500 bushels per year, which is only about 10 bushels per acre average for the approximately 750 acres concerned. If, however, these grounds be utilized as planting grounds for seed oysters, with the yield double the number of bushels planted, a growth possible with good water conditions, the acreage should produce well and yield 100 bushels to the acre. An increased tidal exchange and sufficient depth of water for the operation of boats would be needed. If 500 acres were suitable for cultivation of the 750 acre total in the area concerned, as much as 50,000 bushels per year may be added to the total production, probably more than 10 times the amount possible with the use of the grounds as public oyster rock.

It can be estimated that under the best of conditions oyster production in the Lynnhaven Bay waters can amount to approximately 200,000 bushels per year, which is about double the production average for the years 1929 and 1930, and approximately three times its present value.

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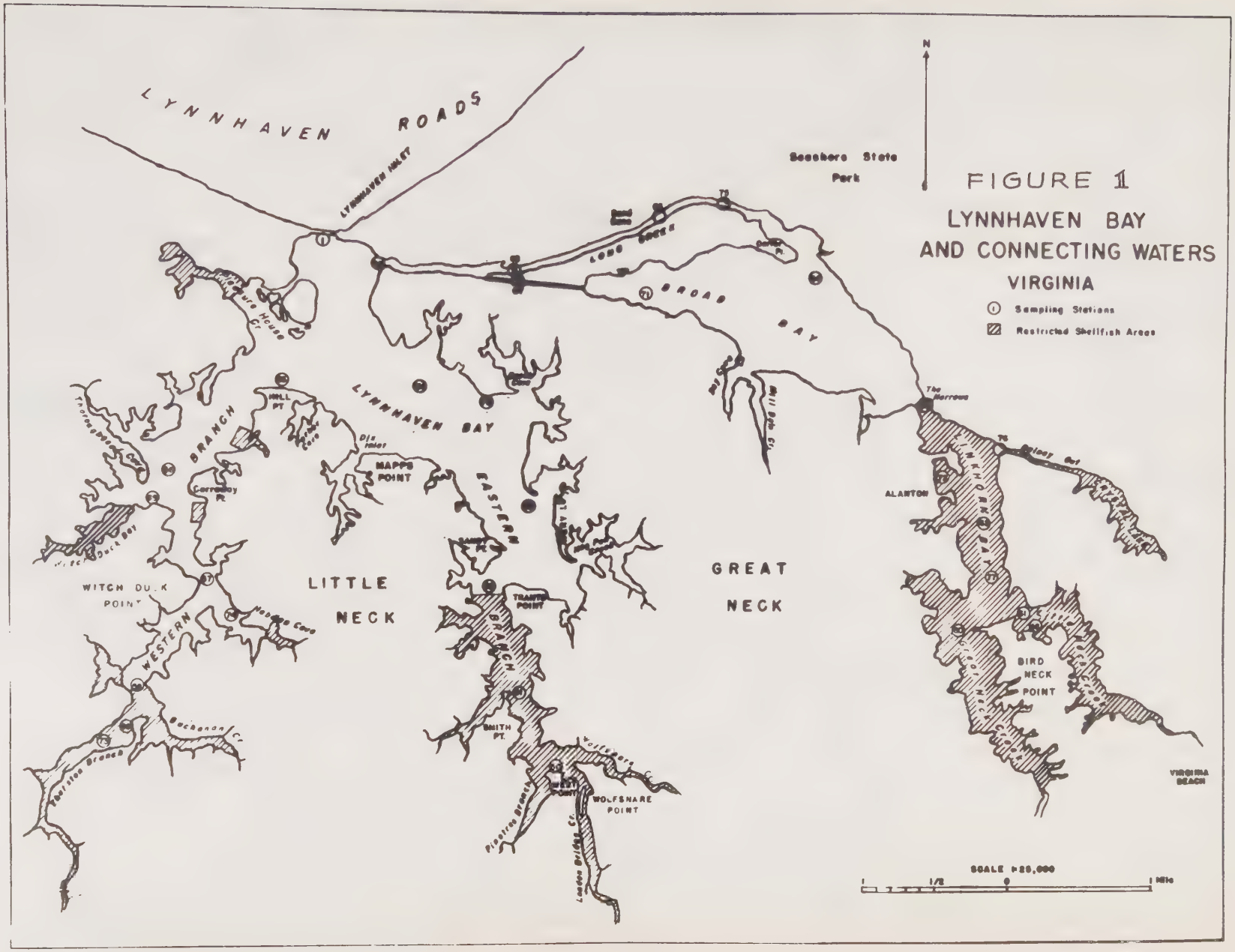

LYNNHAVEN ROADS
LYNNHAVEN INLET
Seashore State Park
N
FIGURE 1
LYNNHAVEN BAY AND CONNECTING WATERS
VIRGINIA
Sampling Stations
Restricted Shellfish Areas
BROAD BAY
LYNNHAVEN BAY
EASTERN BRANCH
WESTERN BRANCH
LITTLE NECK
GREAT NECK
WITCH DUCK POINT
MAPPS POINT
TRANTER POINT
SMITH PT.
WOLFSNARE POINT
BIRD NECK POINT
ALANTON
The Narrows
VIRGINIA BEACH
SCALE 1:25,000
1/2
MILE

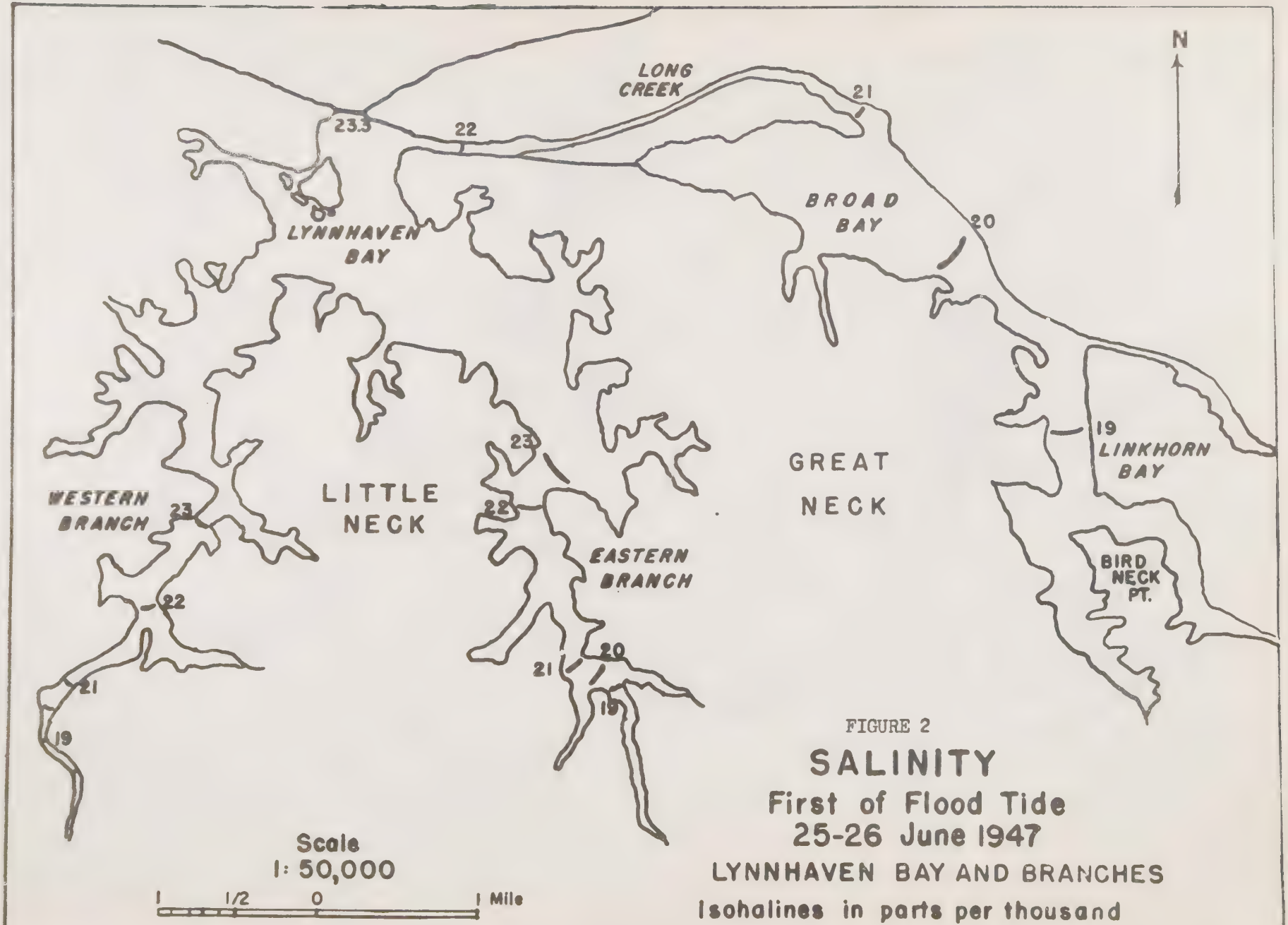


FIGURE 2

SALINITY

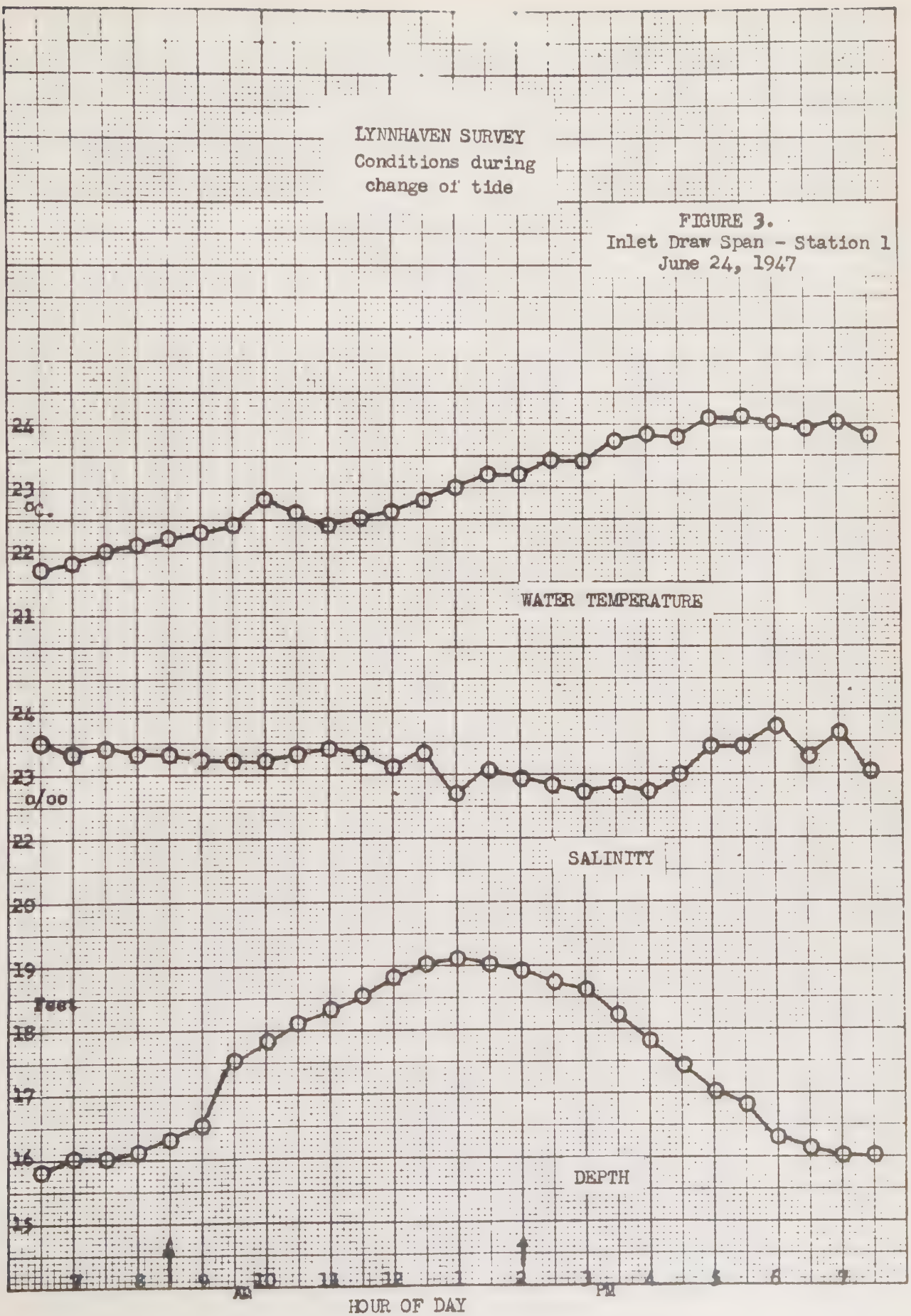
First of Flood Tide
25-26 June 1947

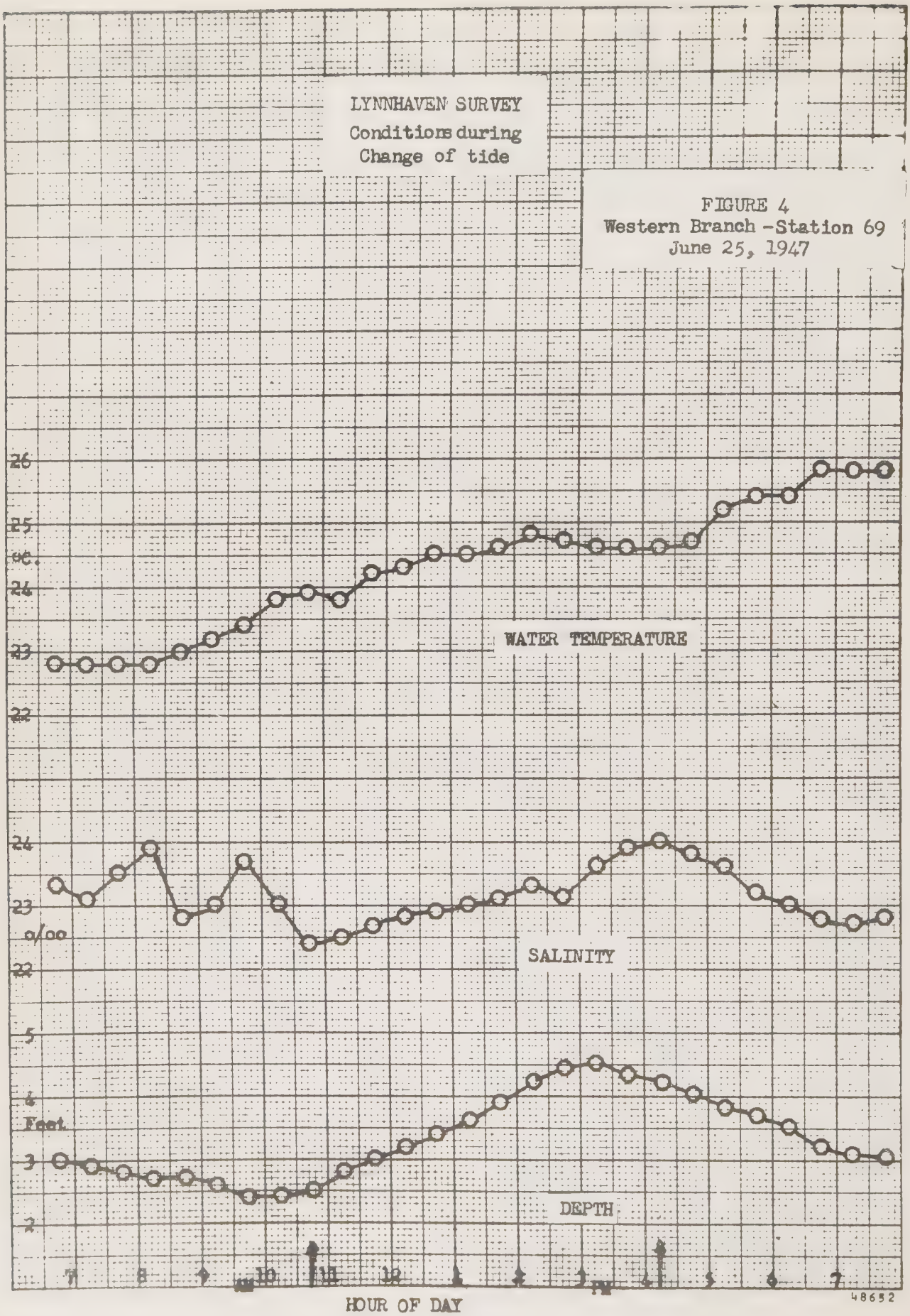
LYNNHAVEN BAY AND BRANCHES

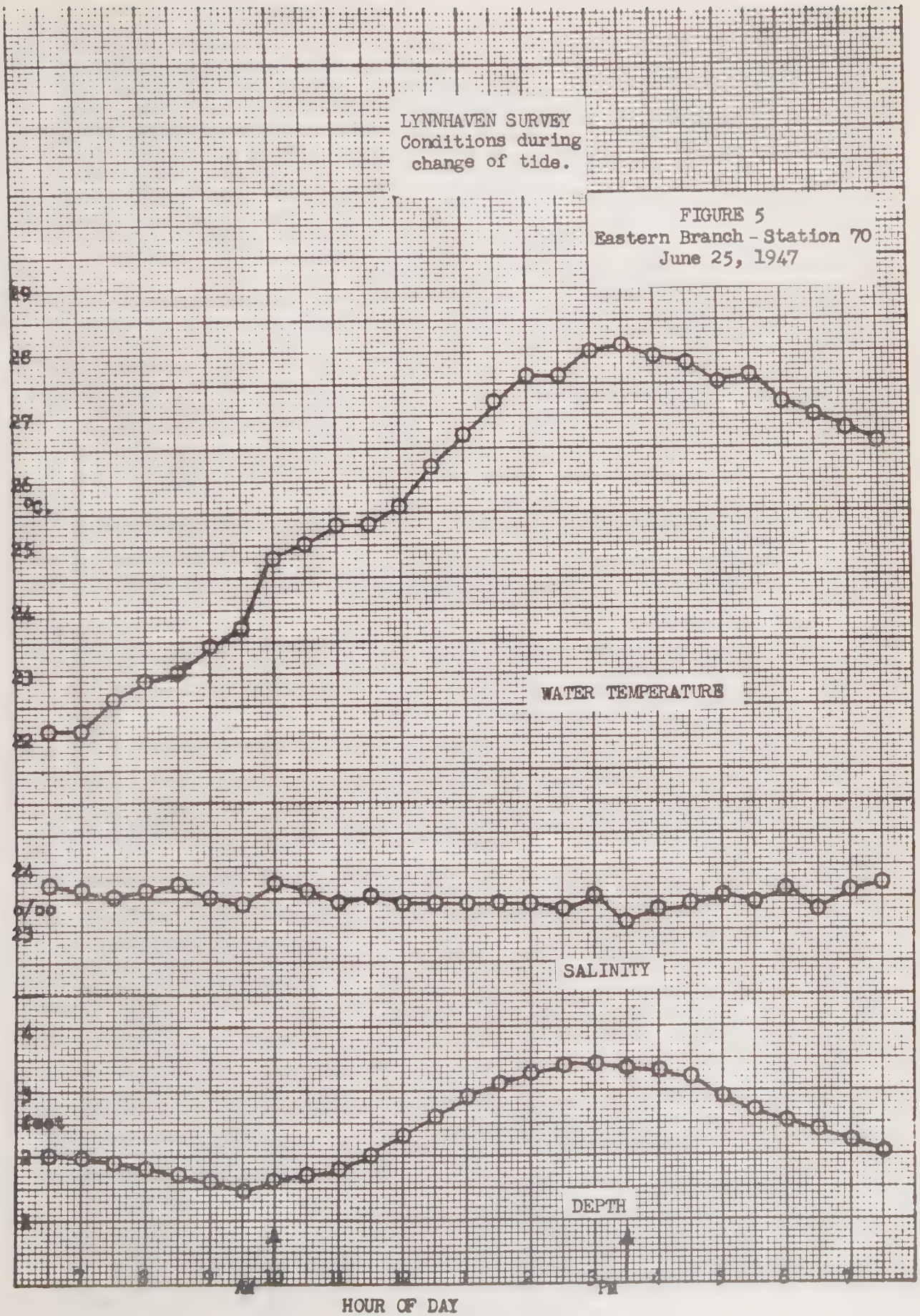
Isohalines in parts per thousand

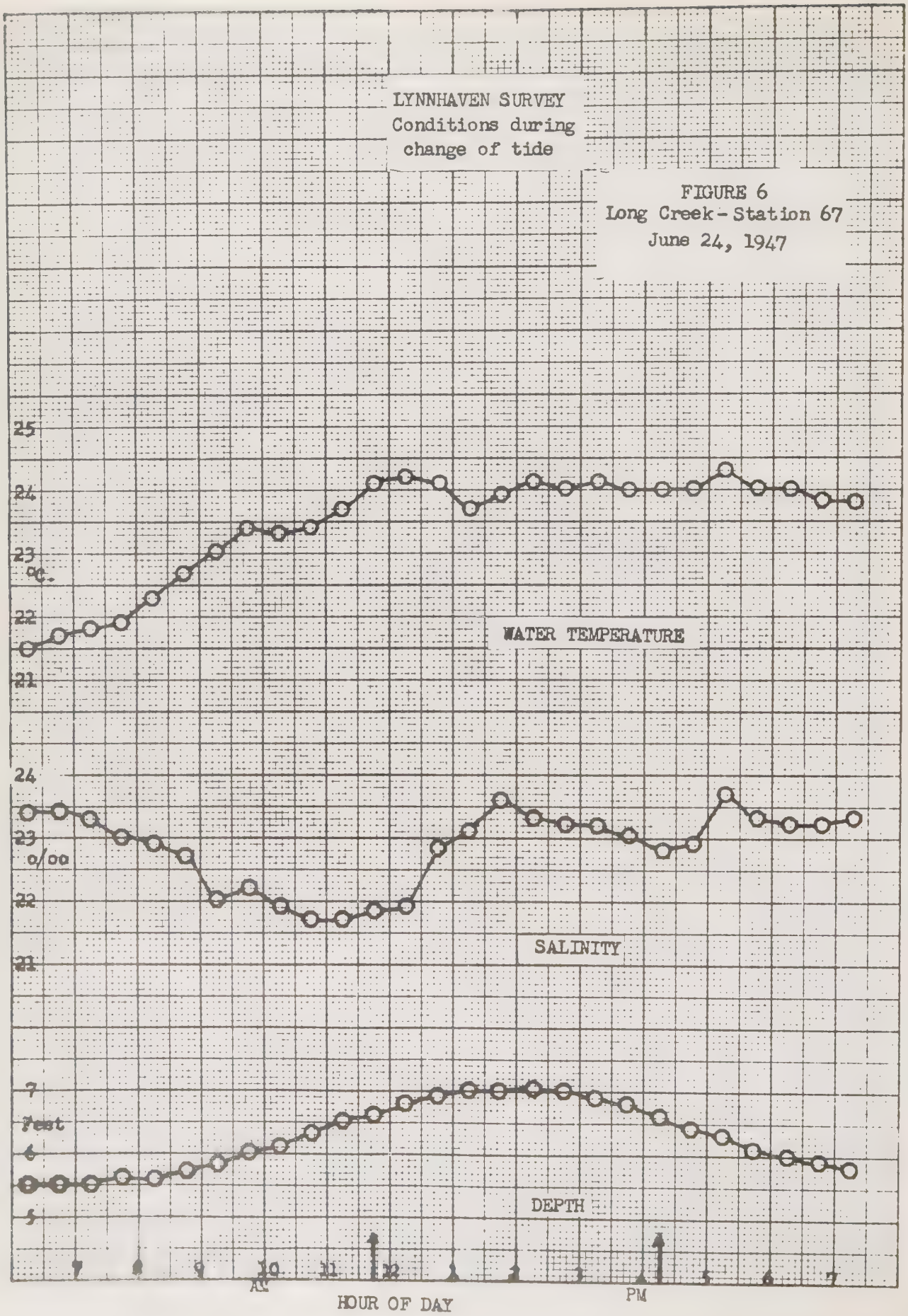
LYNNHAVEN SURVEY
Conditions during
change of tide

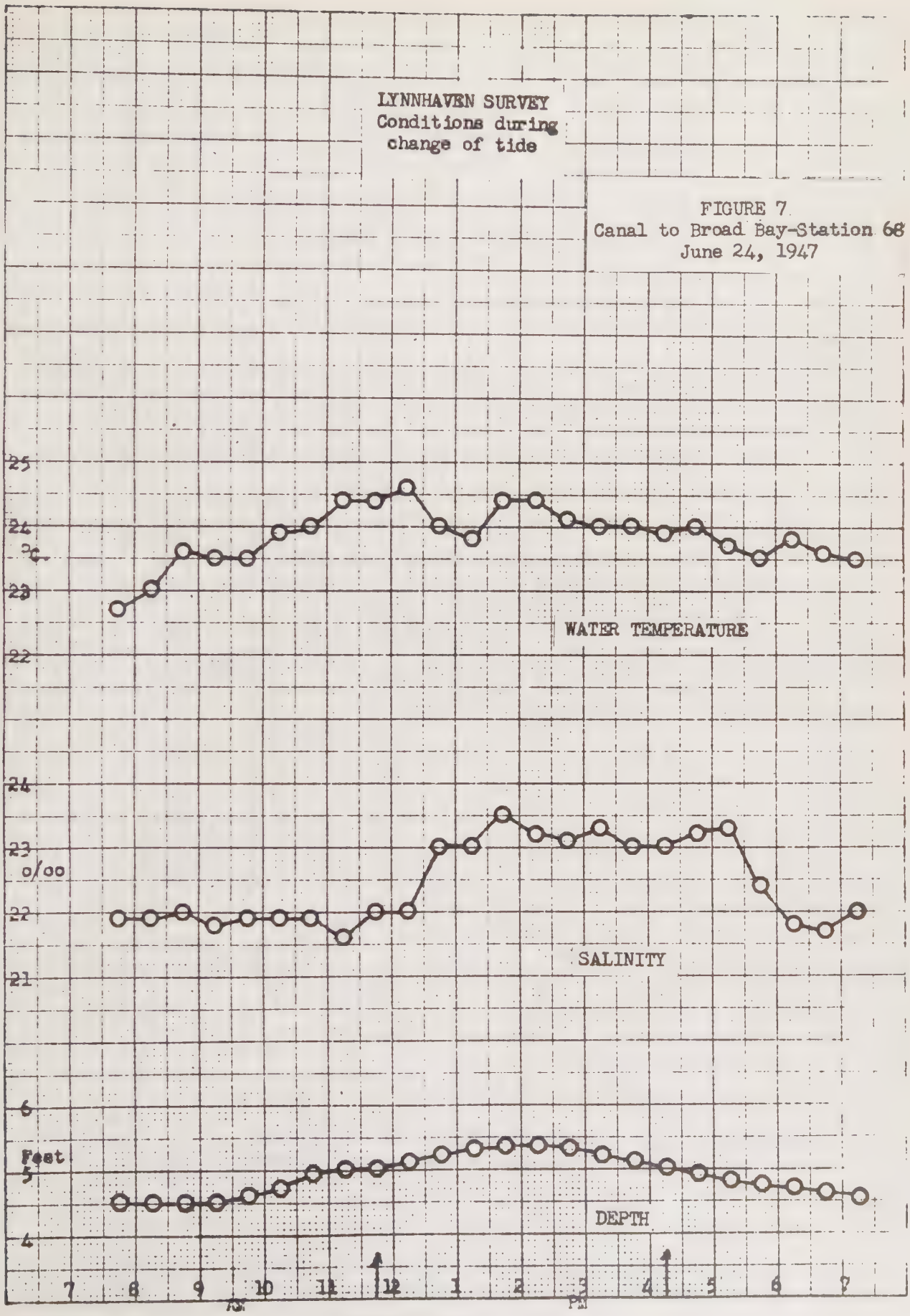
FIGURE 3.
Inlet Draw Span - Station 1
June 24, 1947




LYNNHAVEN SURVEY
Conditions during
Change of tide
FIGURE 4
Western Branch -Station 69
June 25, 1947
26
25
oC.
24
23
22
WATER TEMPERATURE
24
23
o/oo
22
SALINITY
5
4
Feet
3
2
DEPTH
7
8
9
10
11
12
1
2
3
4
5
6
7
PM
HOUR OF DAY
48652

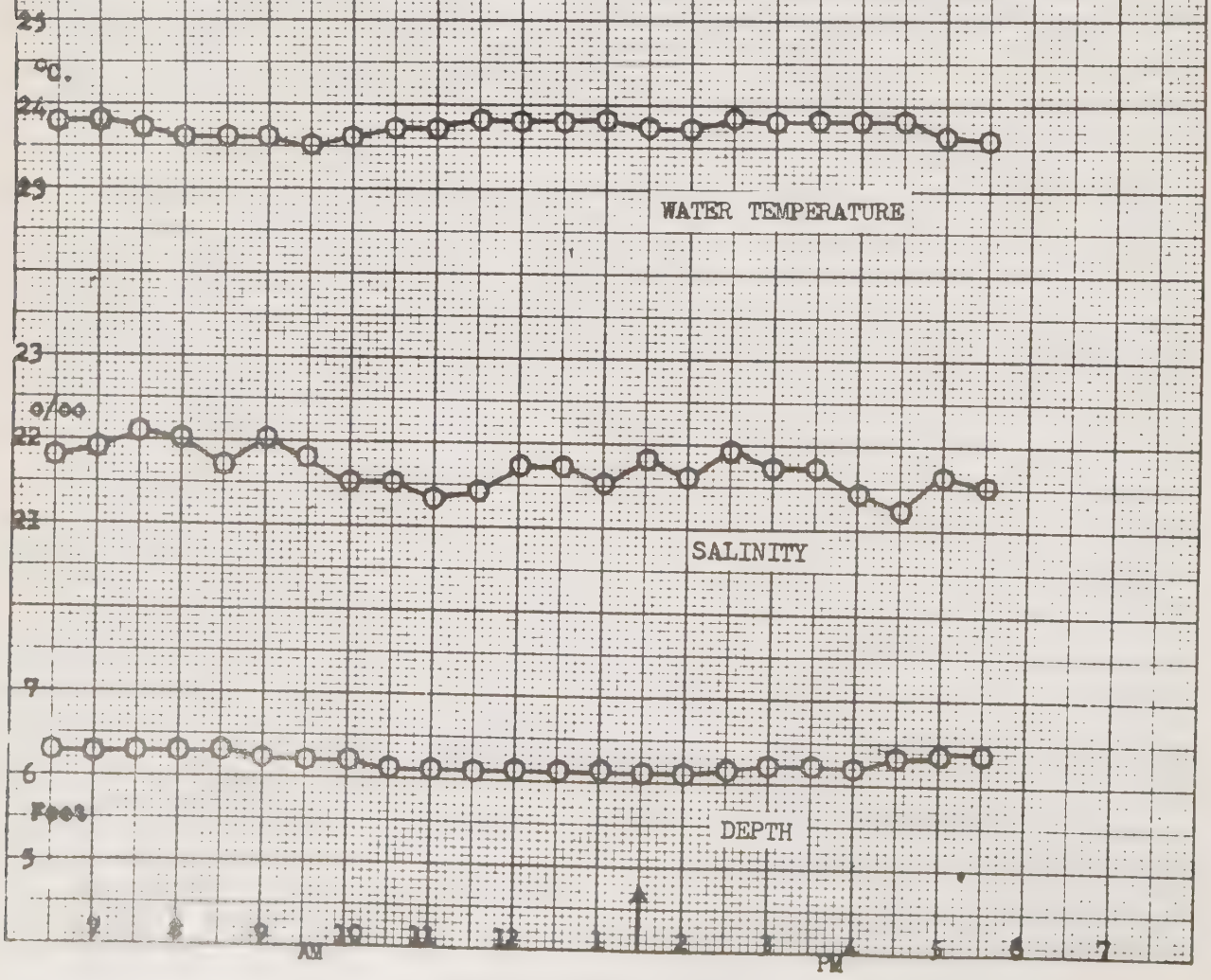

LYNNHAVEN SURVEY
Conditions during change of tide.
FIGURE 5
Eastern Branch - Station 70
June 25, 1947
29
28
27
26
°C
25
24
23
22
WATER TEMPERATURE
24
o/oo
23
SALINITY
4
3
Feet
2
DEPTH
7
8
9
AM
10
11
12
1
2
3
PM
4
5
6
7
HOUR OF DAY


LYNNHAVEN SURVEY
Conditions during
change of tide
FIGURE 6
Long Creek - Station 67
June 24, 1947
25
24
23
°C.
22
21
WATER TEMPERATURE
24
23
o/oo
22
21
SALINITY
7
Feet
6
5
DEPTH
9
10
11
12
1
2
3
4
5
6
7
AM
PM
HOUR OF DAY


LYNNHAVEN SURVEY
Conditions during change of tide
FIGURE 7
Canal to Broad Bay-Station 68
June 24, 1947
25
24
°C
23
WATER TEMPERATURE
22
24
23
o/oo
22
SALINITY
21
6
Feet
5
DEPTH
4
7
8
9
10
11
12
1
2
3
4
5
6
7
AM
PM
HOUR OF DAY

LYNNHAVEN SURVEY
Conditions during
change of tide

FIGURE 8
Broad Bay - Station 71
June 26, 1947



LYNNHAVEN SURVEY
Conditions during
change of tide

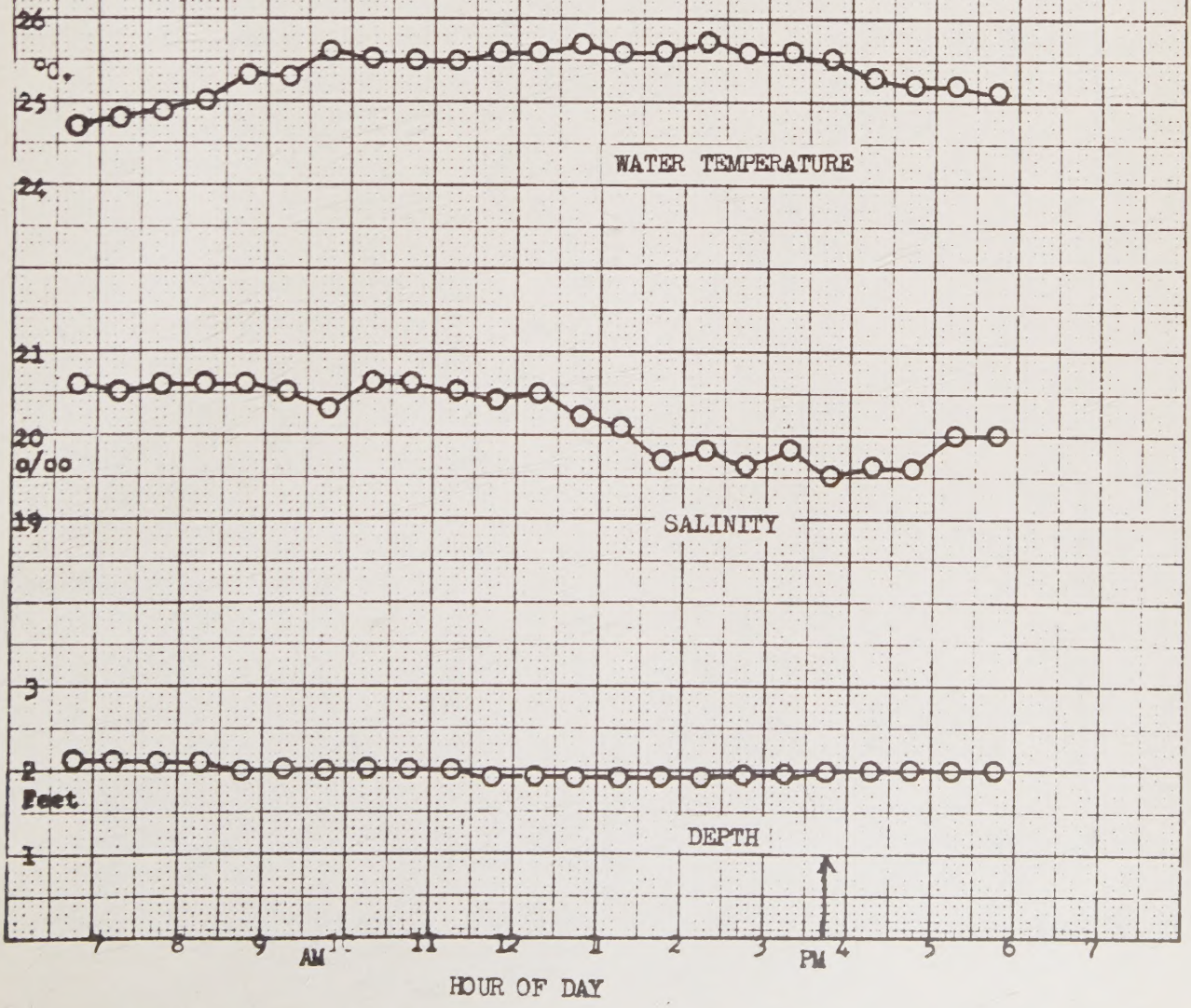



FIGURE 9
Linkhorn Bay - Station 72
June 26, 1947